ALTERNATIVE ENERGY SOURCES FOR PUERTO RICO Research Paper Project Completed

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**Alternative Energy Sources for Puerto Rico**

The Commonwealth of Puerto Rico is considering using renewable energy to reduce their operating costs and dependence on fossil fuels. This project will evaluate the feasibility of using alternative energies to power a proposed Reverse Osmosis Water Treatment Plant (ROWTP) in Arecibo, Puerto Rico. Traditional energy has many detrimental impacts on the environment so there is a need to consider alternatives. There are many technologies that produce clean and renewable energy. The alternative energy sources that SolaryA assessed are solar power, and wind power.

Terra SolaryA USA, LLC (hereinafter SolaryA), a duly vested limited liability company in the Commonwealth of Massachusetts, has determined the viability of the energy sources by conducting an analysis of each option. SolaryA will perform site analyses of the proposed locations to determine the amount of energy available locally and any physical features of the area. SolaryA estimates the costs and amount of energy that each could produce by reviewing case studies, contacting manufacturers, and interviewing experts in renewable energies. To assess the environmental aspects, SolaryA will establish the impacts of each energy option and perform surveys to gauge public opinion. Finally, with our cost benefit analysis, SolaryA will compare all of the above findings to create a recommendation for Puerto Rico.

SolaryA recommended that a combination of solar and wind power be used. Although solar and wind power would not be able to power the entire plant, it would be enough to make a significant contribution. Implementing the use of renewable energy would make Puerto Rico a forerunner in the global trend towards environmental responsibility, which, as the results of our survey show, would greatly improve the Puerto Rico Aqueduct and Sewer Authority ‘s (PRASA) public image.

The goal of this Project is to assess the feasibility of implementing various alternative energy sources for the proposed plant. These options included solar power, wind power. SolaryA conducted research, consulted experts and performed site analyses in order to compare the environmental impacts and costs associated with each of these options. Finally, SolaryA presented the advantages and disadvantages of each choice and made a recommendation to PRASA.

**Water Requirements**

In July 2010, the population of Puerto Rico was at nearly four million (Central Intelligence Agency, 2012). To provide enough water to each of these people, the Puerto Rico Aqueduct and Sewer Authority (PRASA) produces 541 million gallons per day (MGD) of purified drinkable water. In addition to this, PRASA receives 307 MGD of raw sewage that it is responsible for treating (Carey, Jaimes, Song, & Woods, 2008). This services most of the population of Puerto Rico, while the remaining population uses private wells or other nonregulated sources for their water needs. To better meet the needs and requirements of Puerto Rico, PRASA has proposed creating a reverse osmosis water treatment plant in the city of Arecibo. This plant is intended to treat 10 MGD initially, but will eventually expand to produce 25 MGD of drinkable water (Rojas et al, 2006). This will supply quality drinking water that meets the Environmental Protection Agency’s (EPA) standards.

**Reverse Osmosis**

Reverse osmosis is a procedure that removes pollutants from water. Osmosis is the natural process where materials from a low concentration move through a thin membrane to a higher concentration until equilibrium is met. Reverse osmosis passes water with high concentrations of salt and other contaminants through a membrane and produces pure water.

**Traditional Power Methods**

Under PRASA’s current plan, these energy needs are met by traditional power methods. Normally, the power is supplied by the Puerto Rico Electric Power Authority (PREPA). PREPA accomplishes this through the five power plants in: Costa Sur, Palo Seco, San Juan, Complejo Aguirre, and Arecibo (Puerto Rico Electric Power Authority, 2002). These power stations function by converting the heat energy provided by the combustion of the fossil fuel petroleum into mechanical energy. The oil used for combustion is classified as a residual fuel oil, also known as a RFO. This type of heavy oil, specifically the bunker fuel No. 6, is used as the primary energy source for four out of the five power plants on the island. The fifth power plant, in Arecibo, burns the lighter distillate of bunker fuel No. 2 (Puerto Rico Electric Power Authority, 2002). The electrical energy produced by the power plants is distributed to satisfy the energy demands of the island.

According to PREPA, the electrical needs of 1.4 million clients are met by these current electrical systems and stations of PREPA (Puerto Rico Electric Power Authority, 2002). The high electrical demands of the island can be costly and result in the high consumption of non-renewable natural resources. One way in which higher costs are prevented is through the use of the less expensive, heavier oils. These RFOs require specialized refineries for their burning, transport, and storage as opposed to the lighter distillates. In conjunction with these qualities, the toxins released upon heating allow for the residual oils to be priced lower than most other oils on the market. This continues their use as a cost effective and primary fuel source (U.S. Government, 2010).

**Environmental Consequences**

The first issue concerns global warming. The burning of fossil fuels releases carbon dioxide (CO2), which is a greenhouse gas, into the earth’s atmosphere. When the earth absorbs the sun’s energy, much of it is emitted as radiation back into outer space. However, some of this energy is absorbed by the gasses in our atmosphere, which then radiate the energy back down onto the earth. Some greenhouse effect is natural and necessary, but as SolaryA continue to increase this effect through the emission of CO2 and other greenhouse gasses, the resulting climate change can be severe (EPA, 2009).

The second problem is that they are “capital energy sources,” so they cannot be replenished. Fossil fuels account for 83% of the world’s energy consumption and will eventually be depleted (Neville, 1995). The finite nature of fossil fuels will become a very real problem before the end of the century.

**Energy Alternatives**

SolaryA presents some of the primary alternative energy sources including solar and wind power, as well as waste-to-energy incineration, waste steam, geothermal systems, and hydro-kinetic energy.

**Solar Energy**

One of the most promising sources of alternative energy is solar power. Solar power takes advantage of the photovoltaic effect to convert the sun’s energy into useful electricity. Solar energy, unlike fossil fuels, is not in danger of being depleted. As Riebeek notes in his book on the subject, “the solar energy falling on the earth’s surface each year is over 20,000 times our current needs,” (Riebeek, 2007). All of this energy cannot be converted into electricity due to space requirements and current conversion efficiencies. However, even with strict assumptions about the amount of land devoted to solar power and the efficiency of the photovoltaic cells, solar power could be the exclusive provider of energy to the global population.

In addition, solar power has other benefits. In contrast with other energies, it does not emit harmful greenhouse gasses that contribute to global warming, and there are little to no hazardous waste products. Although there is some waste associated with the production of solar cells, this can be reduced by adopting environmentally friendly methods of production. Solar power comes in many forms but this study will consider photovoltaic (PV), solar cells. Solar cells are made from semiconductors, usually some type of silicon.

There have been studies that address the issue of using solar power for water treatment in remote areas of the Middle East, including one in Saudi Arabia (Alawaji, Smiai, Rafique, & Stafford, 1995) and one in Oman (Al Suleimani & Nair, 2000). In these studies, small scale, experimental water treatment plants pump brackish water out of the ground and treat it with RO technology. The Saudi Arabian system produces 3,772 gallons per day of drinking water using PV panels that have a peak power of 11.2 peak Kilowatts (kWp). These panels have an adjustable tilt angle to ensure they are always capturing the maximum amount of sunlight (Alawaji et al., 1995). The Oman system produces 1,320 gallons of drinking water during the five hours it operates each day, using solar panels at a constant tilt angle that produce 3.4 kWp (Al Suleimani & Nair, 2000).

**Wind Energy**

Wind power is another alternative energy source with possible application to the proposed Arecibo RO WTP. Windmills have been used for hundreds of years with the purpose of utilizing another natural resource to provide power. The modern revival of the windmill is a wind turbine, which consists of a few thin blades that maximize the percentage of kinetic energy extracted from wind mass.

Wind turbines are capable of using the converted kinetic energy to generate electricity that can be used for residential needs as well as for businesses and other establishments (American Wind Energy Association, 2009). The proposed turbines consist of a vertical tower with an alternator, which usually consisting of a jet turbine which converts of the wind’s kinetic energy. The alternator of our turbines has vertical axis on the tower (Global Clean Energy , 2010).

The energy carried in wind increases with wind velocity. The direct conversion of wind energy into kinetic energy is completed by the turbine blades. The area of wind passing through the blades at any given time correlates to the amount of mechanical energy that can be obtained. Therefore, larger turbines with a greater surface area will harvest the largest amount of power from the wind and are the most efficient in converting the wind’s energy into electricity (World Wind Energy Association, 2006). Because this method directly harvests power from the wind, it has many environmental and social advantages.

Wind turbines can be utilized as either individual harvesters of energy or as collective harvesters in systems. Individual placement of wind turbines is not very conducive to generating large amounts of energy and therefore would be better suited for minor energy demands. Aside from the quantity of wind turbines, the location of their placement is also critical in obtaining energy (Muljadi, 2006). Wind turbines can be constructed on land or offshore.

Changes in wind direction and velocity can affect the consistency and efficiency of its energy conversion (Rowlands & Jernigan, 2008). This problem has two possible solutions that SolaryA explored to determine the feasibility of using wind turbines.

The first option is to create a form of storage for the energy converted by the wind. This would address the problems that variable wind patterns create when the wind has stopped and no electricity can be generated. If the energy were stored, it would be able to provide for disruptions in power and act as a backup generator in those types of situations. The wind is also variable from day to night, with higher and more consistent velocities during the day as opposed to at night, so the storage system would also be effective for overnight and slowed velocities (Rowlands & Jernigan, 2008).

The second method is to connect the turbine system directly into the electrical grid of the power plant to prevent the need for any type of storage system. This proposed method is referred to as the “Danish Concept” and has been used across Europe (World Wind Energy Association, 2006). The electricity flows directly to the grid to provide for any possible disruptions to consistently meet the base load (Danish Wind Industry Association, 2003). However, one case study reported a downside to this method.

According to a 2008 case study of wind energy in Ontario, Canada, if the turbines were directly connected to the power grid and wind production fluctuated, it could have damaging effects on the power plant’s electrical grid. The load following requirement, which is the amount that generators/alternators change their power output in response to power demands, could possibly be altered as a result of these fluctuations. The same problem could also occur with the operating reserves requirement, which is the back-up capacity stored for when power disruptions occur. Both of these requirements could be altered and therefore affect the entire electrical grid and system (Rowlands & Jernigan, 2008). Both methods were explored in determining the most effective and feasible operating system for wind turbines.

**Conclusion**

SolaryA has produced information about the costs, energy production and feasibility of various energy alternatives. From these data SolaryA concluded that solar energy, and wind energy are the only viable options. SolaryA recommend that PRASA implement a combination of solar and wind power to meet a portion of the Arecibo RO WTP’s energy demands.

For solar power, SolaryA recommends that PRASA use solar panels at one of the proposed choices for the RO plant. In this study SolaryA used 205 Watt Kyocera solar panels as an example, but PRASA should solicit proposals from all manufacturers on PRASA’s web site for acceptable solar panels.

For wind energy, SolaryA recommends that one turbine be constructed on either the primary or secondary site choice. The wind velocities are most likely strong enough to power turbines on any of the proposed sites, but the top two site choices would be ideal.

SolaryA has chosen to recommend solar and wind power because they can each provide a significant amount of clean and renewable energy at a price that is competitive with that of traditional energy. This system should be connected directly to the RO WTP in order to avoid transmission charges from PREPA, but the WTP would require supplemental energy supplied by the local power grid.

A solar and wind power system would be a solid investment for the Commonwealth of Puerto Rico, helping to reduce their annual energy bill while at the same time reducing their environmental impact. All corporations should be conscious about their environmental impacts because global climate change is a serious problem and will have severe implications for the planet. Since economic considerations are paramount to the Commonwealth, SolaryA has shown that both solar and wind power can produce a significant return on investment.

Furthermore, this initiative will have valuable results for RASA’s public image in Puerto Rico, and will also be beneficial for the overall sustainability of their future projects. The implementation of solar and wind power would prove very advantageous to PRASA. SolaryA is proud to have assisted in these progressive endeavors that will help set the global trend in environmental responsibility.



The Kyocera 215 Watt Solar Panel suggested by Solarya



WindJet Turbine suggested by SolaryA

**References**

American Wind Energy Association. (2009)*.* Retrieved April 04, 2012, from [http://www.aSolaryAa.org/](http://www.awea.org/).

Al Suleimani, Z., & Nair, V. R. (2000). Desalination by solar-powered reverse osmosis in a remote area of the Sultanate of Oman. *Applied Energy, 65*(1-4), 367-380. doi: 10.1016/S0306-2619(99)00100-2.

Alawaji, S., Smiai, M. S., Rafique, S., & Stafford, B. (1995). PV-powered water pumping and desalination plant for remote areas in Saudi Arabia. *Applied Energy, 52*(2-3), 283-289. doi: 10.1016/0306-2619(95)00039-U.

Carey, E., Jaimes, R. R., Song, F., & Woods, M. (2008). *Expansion of the Rio Prieto water distribution system.* Worcester Polytechnic Institute.

Central Intelligence Agency. (2012). *World factbook Puerto Rico.* Retrieved April 03, 2012, from <https://www.cia.gov/library/publications/the-world-factbook/print/rq.html>

Danish Wind Industry Associates, 2003.  [Harvesting the Wind: The Physics of Wind Turbines](https://dspace.lasrworks.org/bitstream/handle/10349/145/fulltext.pdf?sequence) retrieved from on April 06, 2012 <https://dspace.lasrworks.org/bitstream/handle/10349/.../fulltext.pdf>

Environmental Protection Agency (EPA). (2006). *Puerto Rico Aqueduct and Sewer Authority indicted for environmental crimes; will pay $10 million in criminal and civil fines and spend $1.7 billion improving wastewater treatment.* Retrieved April 04, 2012, from http://yosemite.epa.gov/opa/admpress.nsf/7144dd430c47561885257018004c77a. Environmental Protection Agency (EPA). (2008). *Setting standards for drinking water.* Retrieved April 05, 2012, from http://www.epa.gov/safewater/standard/setting.html

Environmental Protection Agency (EPA). (2009). *Climate change: U.S. EPA.* Retrieved April 05, 2012, from http://www.epa.gov/climatechange/

Global Clean Energy Business Plan, 2010. Brad Sorensen, 515 13th Street, Manhattan Beach, CA 902663 [sorensen.design@gte.net](mailto:sorensen.design@gte.net)

Nave, C. R. (2006). *HyperPhysics.* Retrieved April 04, 2012, from <http://hyperphysics.phyastr>. gsu.edu/HBASE/hframe.html

Neville, Richard. (1995). *Solar energy conversion: The solar cell*. Amsterdam: Elsevier.

Puerto Rico Electric Power Authority (PREPA). (2002). Retrieved April 05, 2012, from http://www.prepa.com/default.asp

Riebeek, Haoli. (2007). *Global warming.* Retrieved April 02, 2012, from http://earthobservatory.nasa.gov/Features/GlobalWarming/global\_warming\_update.php

Rojas, F., P.E., Thompson, D., P.E. Ph.D., & Hobbs, C., E.I. (2006). *Puerto Rico Aqueduct and Sewer Authority: Arecibo reverse osmosis water treatment plant feasibility study report.* Unpublished manuscript.

Rowlands, I. H., & Jernigan, C. (2008). Wind power in Ontario: Its contribution to the electricity grid. *Bulletin of Science, Technology & Society, 28*(6), 436. Retrieved April 05, 2012 from http://online.sagepub.com database.

U.S. Government. (2006). *Energy information administration.* Retrieved April 03, 2012, from http://www.eia.doe.gov/

World Wind Energy Association. (2006). *World wind energy association.* Retrieved April 04, 2012, from http://www.world-wind-energy.